Ecosystem service values of gardens in the Yellow River Basin, China

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Abstract: Studies on the ecosystem service value (ESV) of gardens are critical for informing evidence-based land management practices based on an understanding of the local ecosystem. By analyzing equivalent value factors (EVFs), this paper evaluated the values of 11 ecosystem services of gardens in the Yellow River Basin of China in 2019. High-precision land use survey data were used to improve the accuracy of the land use classification, garden areas, and spatial distribution of the ESVs of gardens. The results showed that garden ecosystem generally had high ESVs, especially in terms of the ESV of food production, which is worthy of further research and application to the practice of land use planning and management. Specifically, the value of one standard EVF of ecosystem services in 2019 was 3587.04 CNY/(hm²·a), and the ESV of food production of gardens was much higher than that of croplands. Garden ecosystem provided an ESV of 1348.66×10⁸ CNY/a in the Yellow River Basin. The areas with the most concentrated ESVs of gardens were located in four regions: downstream in the Shandong-Henan zone along the Yellow River, mid-stream in the Shanxi-Shaanxi zone along the Yellow River, the Weihe River Basin, and upstream in the Qinghai-Gansu-Ningxia-Inner Mongolia zone along the Yellow River. The spatial correlation of the ESVs in the basin was significant (global spatial autocorrelation index Moran's I=0.464), which implied that the characteristics of high ESVs adjacent to high ESVs and low ESVs adjacent to low ESVs are prominent. In the Yellow River Basin, the contribution of the ESVs of gardens to the local environment and economy varied across regions. We also put forward some suggestions for promoting the construction of ecological civilization in the Yellow River Basin. The findings of this study provide important contributions to the research of ecosystem service evaluation in the Yellow River Basin.

Keywords: ecosystem service evaluation; garden ecosystem; equivalent value factors; spatial autocorrelation analysis; Yellow River Basin

1 Introduction

In modern society, environmental deterioration has led to a growing awareness of ecosystem service value (ESV) and its significance to human beings (de Groot et al., 2012). A fundamental

study of Costanza et al. (1997) on the value of the world's ecosystem services quantitatively evaluated ecosystem services and applied the results to ecosystem protection, thus demonstrating that ecosystem services are an important subject of scientific research for responding to global change (Fu and Zhang, 2014; Costanza et al., 2017). With fruitful efforts of studies such as Daily (1997), Costanza et al. (1997, 2014), and Xie et al. (2003, 2015, 2017), the theories and methodologies for ecosystem service evaluation have been constantly improved. Ecosystem services refer to the benefits to human wellbeing offered by the natural environment, including both direct and indirect contributions (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005). Based on this definition, scholars have carried out researches on the ESVs of forests (Ojea et al., 2016), wetlands (Wang et al., 2007), croplands (Xie and Xiao, 2013), grasslands (Qu et al. 2021.), and many other ecosystems.

However, the types of ecosystem services are still not well understood (Costanza et al., 2017) and remain controversial (Thompson and Barton, 1994; McCauley, 2006), and the classification of ecosystems is also inadequately refined. For example, there are few studies focused on the ESVs of gardens, although garden ecosystem plays an important role in contributing to ecosystem health (Zhang et al., 2020). Some researchers have studied the ecosystem services of various types of gardens, such as health clinic gardens (Cilliers et al., 2018), urban gardens (Lin and Egerer, 2019), and home gardens (Calvet-Mir et al., 2012). For instance, Baumgärtner and Bieri (2006) explored the qualitative evaluation of services provided by fruit tree ecosystem in an ecological engineering context. Tian et al. (2011, 2014) systematically assessed soil conservation and gas regulation services of orchards in the Pinggu District of Beijing City, China. Willemen et al. (2019) stressed the importance of aggregate effects on ecosystem services from the certification of tea farming. However, few scholars have realized the particularity of garden ecosystem and its management purpose, and some studies even considered gardens as a subset of forests in terms of the ESV (Gong et al., 2017). Therefore, currently available literature on garden ecosystem lacks depth and is relatively sporadic, thus making it difficult to develop a comprehensive and detailed understanding of garden ecosystem.

In China's land classification system, garden is an important land category, and the relevant ecosystem has distinctive characteristics (MNR, 2021). In the land use surveys, garden including orchard, tea garden, and other garden types is defined as "area occupied by intensive planting of perennial woody or herbaceous crops for fruits, leaves, roots, stems, juice, etc., with a coverage greater than 50.00% or the number of plants per unit area greater than 70.00% of the reasonable number of plants" (AQSIQ and SAC, 2017). Garden ecosystem can also provide supporting, provisioning (Yu et al., 2018), regulating, and cultural ecosystem services. For instance, garden ecosystem in China produced 262.04×10^6 t fruits and 2.46×10^6 t tea in 2019, accounting for 30.27% and 40.30% of the world's total yield, respectively (National Bureau of Statistics, 2020a).

Quantitative evaluation of services provided by garden ecosystem would refine the classification of global ecosystems and improve the collective understanding of them. Scientists have created a considerable number of methods to estimate the ESV, such as unit value (Costanza et al., 2017), equivalent value factor (EVF) (Xin et al., 2018), production-oriented valuation, replacement costs, and shadow pricing (Wang et al., 2007). Many related models such as the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) (Nelson et al., 2009; Terrado et al., 2016), Multiscale Integrated Model of Ecosystem Services (MIMES) (Boumans et al., 2015), Artificial Intelligence for Ecosystem Services (ARIES) (Villa et al., 2009), and Ecosystem Portfolio Model (EPM) (Labiosa et al., 2013) are built on the basis of multi-source data. Literature analysis (An et al., 2022) found that, although the EVF method shows inherent subjectivity to a certain extent, it requires relatively fewer data and the results are easy to understand. This method is especially suitable for studies on a regional scale (Costanza et al., 2014) and is widely used and universally recognized. Additionally, Chinese scholars have conducted many studies using this method such that results would be comparable to prior literature (An et al., 2022). Other methods, as mentioned, tend to focus on a single type of

ecosystem service and require large amounts of data and related parameters. Although this could reduce the subjectivity of the results to some extent, the process is very time- and labor-intensive, and the coordination of multiple methods would be impractical. Therefore, in view of the timeliness of data, the availability of parameters, and the comparability of evaluation results, the EVF method was used as the main quantitative evaluation approach for garden ecosystem services in this paper.

The Yellow River Basin of China is a cradle of human civilization; the basin spans many climatic and geomorphic regions, and the distribution of water resources exhibits great disparity from southeast to northwest. The basin is an important fruit-producing region in China due to high yield, excellent variety, wide distribution, and long history of fruit tree cultivation. This study selected gardens in the Yellow River Basin for the ESV assessment, and the results will help to rediscover this ancient region and explore the impact of natural geographical factors (including topography, climate, and water resources) on the ESVs of gardens.

The detailed research objectives are to: (1) calculate and discuss the food supplying service value of garden ecosystem based on statistical data; (2) generalize the quantity and distribution characteristics of the ESVs of gardens; and (3) provide reasonable policy suggestions for protecting the garden ecosystem and guidance for the rational utilization of garden ecosystem in the Yellow River Basin. Furthermore, this paper attempts to offer a case study for evaluating a special type of land use or biome at the local scale, with the aim of providing a reference for global ecosystem service evaluation, sustainable development, and ecological civilization construction.

2 Materials and methods

2.1 Study area

The Yellow River Basin refers to the geographical and ecological region affected by the Yellow River system from the source to the estuary (Gu et al., 2021; Liu et al., 2021). It is located at 96°–119°E longitude and 32°–42°N latitude. The region is 1900 km long from east to west and 1100 km long from north to south. It spans three major ladders in China (Fig. 1), four geomorphic
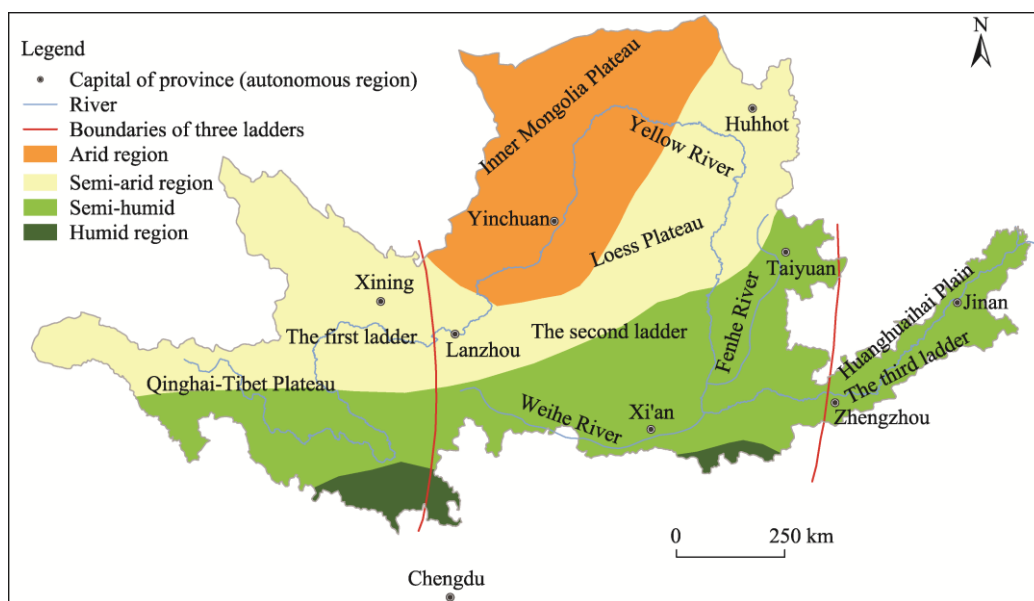
Fig. 1 Overview of the Yellow River Basin. Xining is the capital of Qinghai Province, Lanzhou is the capital of Gansu Province, Chengdu is the capital of Sichuan Province, Yinchuan is the capital of Ningxia Hui Autonomous Region, Huhhot is the capital of Inner Mongolia Autonomous Region, Xi'an is the capital of Shaanxi Province, Taiyuan is the capital of Shanxi Province, Zhengzhou is the capital of Henan Province, and Jinan is the capital of Shandong Province.

units (the Qinghai-Tibet Plateau, the Inner Mongolia Plateau, the Loess Plateau, and the Huanghuaihai Plain), and four climatic zones (arid, semi-arid, semi-humid, and humid climate). The total area of the Yellow River Basin is 1.15×10^6 km^2, including nine province/autonomous region-level areas (Qinghai Province, Gansu Province, Sichuan Province, Ningxia Hui Autonomous Region, Inner Mongolia Autonomous Region, Shaanxi Province, Shanxi Province, Henan Province, and Shandong Province). The area of gardens in the Yellow River Basin accounts for 1.40% of the total area of the basin, and the fruit output is 95.00×10^6 t, accounting for 34.80% of the total output in China. Among them, apples, pears, grapes, and other fruits are famous all over the world.

2.2 Data sources

Based on data of the scope of the Yellow River Basin from previous studies (Yang et al., 2002; Liu et al., 2021), we selected 365 research units (including cities, counties, and banners) in the Yellow River Basin as research objects. The spatial vector data were derived from the Resources and Environmental Science Data Center of the Chinese Academy of Sciences (http://www.resdc.cn). We updated and adjusted these data according to the administrative division. We calculated the output values and yields of various gardens in 2019 based on the China Rural Statistical Yearbook (National Bureau of Statistics, 2020b). The types and areas of gardens were obtained from the field survey data of land use status in 2019. Further, the data used to calculate the ratio coefficient of production and price index were derived from the China Statistical Yearbook (National Bureau of Statistics, 2011, 2020a).

2.3 Value of one standard EVF (equivalent value factor)

To reflect the current regional situations in the Yellow River Basin and to reduce the confounding effects of price levels and indices of agricultural producers in 2010 and 2019, we adjusted the one standard EVF for the grain yield of cropland per unit area in the Yellow River Basin and in China in 2019 (Xie et al., 2015). The value of one standard EVF in the Yellow River Basin could be derived from the following equation:

$$D_b = D \times p \times y = D \times \frac{P_{2019}}{P_{2010}} \times \frac{Y_{b2019}}{Y_{c2019}} \, , \qquad (1)$$

where D_b is the value of one standard EVF in the Yellow River Basin in 2019; D is the value of one standard EVF in China, which is a constant of 3406.50 CNY/(hm^2·a) (Xie et al., 2015); p is the price index ratio that is used to correct for food price factors; and y is the average grain yield ratio. In the formula, P_{2010} and P_{2019} are the agricultural producer price indices of the nine provinces (autonomous regions) in the Yellow River Basin in 2010 and 2019, respectively; and Y_{b2019} and Y_{c2019} are the grain yields per unit area in the Yellow River Basin and in China in 2019 (t/hm^2), respectively. Our result showed that the value of one standard EVF in the Yellow River Basin in 2019 was 3587.04 CNY/(hm^2·a).

2.4 EVFs of garden ecosystem services

2.4.1 Fundamental function

The definition of garden is that the purpose of planting in a garden is to achieve a certain economic value by collecting food or raw materials. Dominated by relatively individual deciduous broad-leaved tree species, gardens have a high canopy coverage and developed root systems. Some services of gardens such as gas regulation, climate regulation, environmental purification, and soil conservation, are similar to those of forests, but unlike forests, there are few herbaceous plants in gardens. Garden ecosystem is greatly affected by human activities such as irrigation, fertilization, and elimination of pests and diseases, which could increase or decrease the service values of garden ecosystem to some extent.

The EVFs represent the potential contribution factors of ecosystems in term of service values, which are positively correlated with the biomass of ecosystems in general (Xie et al., 2003, 2015).

Based on the definition of garden and the ecological service characteristics of garden ecosystem, we assumed that the EVF of the kth ecosystem service of gardens could have functional relationships with the same ecosystem service of other ecosystems such as forests, croplands, grasslands, etc. Theoretically, if the relative contribution of gardens and other ecosystems were scientifically measured, the EVFs of gardens could be accurately calculated using the following equation:

$$F_{gk} = f(F_{1k}, F_{2k}, \cdots, F_{ek}),$$ (2)

where F_{gk} (in which g represents the garden ecosystem) is the EVF of the kth ecosystem service of garden ecosystem; and F_{ek} is the EVF of the kth ecosystem service in the eth ecosystem (such as forests, croplands, grasslands, etc.) (Xie et al., 2015).

2.4.2 Food production service value of gardens

Food production service value per unit area is regarded as the basic value for the assessment of ecosystem services. The economic value of gardens mainly depends on the yield of fruits, i.e., food production capacity. The definition of EVF shows that the ESV of food production is proportional to the food production capacity of the ecosystem. Comparing the economic output value of gardens per unit area with that of croplands per unit area in the Yellow River Basin, the relationship of the EVFs between gardens and croplands can be described by the following equation:

$$F_{Gp} = F_p \times \frac{V_{Gm}}{V_{Cm}},$$ (3)

where F_{Gp} is the EVF of food production service value of garden ecosystem (CNY/(hm^2·a)); F_p is the EVF of food production service value of croplands (CNY/(hm^2·a)); V_{Gm} is the output value of gardens per unit area in 2019 (CNY); and V_{Cm} is the output value of croplands per unit area in 2019 (CNY).

2.5 Spatial autocorrelation analysis

The spatial autocorrelation analysis method was used to reveal the spatial correlation and agglomeration characteristics of the ESVs of gardens in the Yellow River Basin. We calculated the global spatial autocorrelation index (Moran's I) according to the following equation

$$\text{Moran's } I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\left(\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \right) \sum_{i=1}^{n} (x_i - \overline{x})^2},$$ (4)

where Moran's I is the spatial autocorrelation index of the ESVs of gardens; n is the number of basic research units in the study area (n=365 in this study); x_i and x_j are the annual ESVs of gardens in research units i and j (CNY/a), respectively; $\overline{x}$ is the average annual ESV of gardens (CNY/a); and w_{ij} is the spatial weight matrix, representing the adjacency relationship between the ith and j^{th} research units. The Queen algorithm was used to determine the adjacency relationship. When the research units are adjacent in space, the adjacency relationship value is 1, and when the research units are not adjacent, the value is 0. The range of the global spatial autocorrelation index (Moran's I) is from –1.000 to 1.000. A value of Moran's I higher than zero indicates that the spatial distribution of the ESVs of gardens is positively correlated, that is, high values are adjacent to high values or low values are adjacent to low values, and the ESVs of each research unit are spatially clustered. Meanwhile, a value of Moran's I lower than zero means that the spatial distribution of the ESVs of gardens is negatively correlated, that is, high values are adjacent to low values or *vice versa*, and the ESVs of each research unit are spatially dispersed. A value of Moran's I equals to zero indicates that there is no spatial autocorrelation of research

units, and the ESVs of each research unit follow a random spatial distribution.

3 Results

3.1 EVFs of garden ecosystem in the Yellow River Basin

By referring to previously published methods (Chen and Wu, 2011; Tian and Wang, 2011; Tian and Liu, 2014) and comparing garden ecosystem with other ecosystems, we obtained the EVFs of garden ecosystem in the Yellow River Basin (Table 1). The EVFs in Table 1 represented the standardized value of various ecosystem services provided by different gardens, which were multiples of the one standard EVF. When EVF=1.00, the value of such ecosystem service of such garden was 3587.04 $CNY/(hm^2 \cdot a)$. It clearly shows that garden ecosystem generally had high ESVs, especially in terms of the ESV of food production, and the ESV of food production of gardens was much higher that of croplands.

Table 1 Equivalent value factors (EVFs) of garden ecosystem for different garden types in the Yellow River Basin in 2019

Ecosystem services		EVFs		
		Orchard	Tea garden	Other garden types
Provisioning services	Food production[*]	6.03	4.92	5.31
	Raw materials[**]	0.66	0.43	0.66
	Water supply[**]	0.02	0.02	0.02
Regulating services	Gas regulation[**]	1.66	0.90	1.66
	Climate regulation[**]	5.16	2.89	5.16
	Environmental purification[**]	1.49	0.84	1.49
	Water regulation[**]	3.76	2.37	4.74
Supporting services	Soil conservation[**]	2.03	1.10	2.03
	Nutrient cycling[**]	0.15	0.08	0.15
	Biodiversity[**]	1.85	1.01	1.85
Cultural services	Aesthetic landscape[**]	1.12	0.75	1.12

Note: *, values were calculated using Equation 3; **, values were obtained from the study of Xie et al. (2015).

3.2 Characteristics and distribution patterns of the ESVs of gardens

3.2.1 Quantitative characteristics of the ESVs of gardens

The results shown in Table 2 indicate that garden ecosystem in the Yellow River Basin could provide an ESV of 1348.66×10^8 CNY/a, in which orchard contributed 81.72%, tea garden accounted for 0.01%, and other garden types contributed 18.26%. Table 2 shows that the regulating service value of garden ecosystem accounted for more than half of the total ESV. It is also evident that the total ESV of other services was higher compared to the ESV of food production. For the ecologically fragile arid and semi-arid areas, regulating services and supporting services are also particularly important.

3.2.2 Distribution patterns of the ESVs of gardens

The distribution of the ESVs of gardens in the Yellow River Basin was extremely uneven. In the 365 research units, the maximum ESV was 49.03×10^8 CNY/a, the minimum was 0.00 CNY/a, and the average was 3.69×10^8 CNY/a. The frequency histogram shows that among the 365 research units in the basin, there were 51 units with the ESVs of $0.00-0.10 \times 10^8$ CNY/a, accounting for 13.97% of the total research units (Fig. 2). Most of the ESVs were in the range from 1.00×10^8 to 5.00×10^8 CNY/a, occurring in 99 research units, followed by a small number of research units (67), with the ESVs ranging from 0.10×10^8 to 0.50×10^8 CNY/a. Moreover, there were 73 research units with ESVs of above 10.00×10^8 CNY/a.
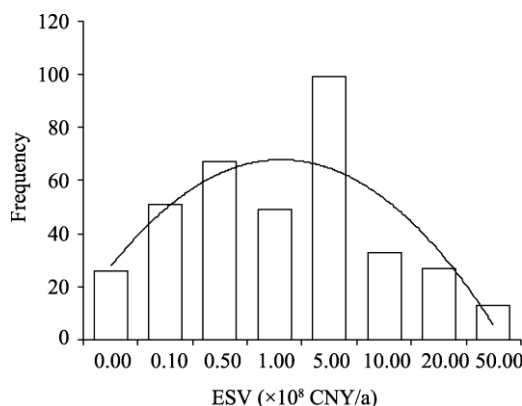
Table 2 Ecosystem service values (ESVs) of gardens in the Yellow River Basin in 2019

| Ecosystem services	ESV ($\times10^8$ CNY/a)	Percentage (%)
Provisioning services	370.11	27.44
Food production	331.86	24.61
Raw materials	37.12	2.75
Water supply	1.13	0.08
Regulating services	688.89	51.07
Gas regulation	93.37	6.92
Climate regulation	290.24	21.52
Environmental purification	83.81	6.21
Water regulation	221.47	16.42
Supporting services	226.66	16.82
Soil conservation	114.17	8.47
Nutrient cycling	8.44	0.63
Biodiversity	104.05	7.72
Cultural services	63.00	4.67
Aesthetic landscape	63.00	4.67
Total	1348.66	100.00

Figure 3 shows the spatial distribution of the ESVs of gardens in the Yellow River Basin. The higher ESVs were mainly observed along rivers in the basin and were concentrated in four regions. The first region (I) was downstream in the Shandong-Henan zone along the Yellow River, extending from Mianchi County in Henan to the Yellow River estuary. This region was in a semi-humid area, where all research units had a certain area of gardens, among which the ESVs of five research units exceeded 10.00×10^8 CNY/a. In this region, the Dawen River tributary basin in Shandong exhibited the most concentrated ESVs. The second region (II) was mid-stream in the Shanxi-Shaanxi zone along the Yellow River, extending from Fugu County of Shaanxi in the north to Danfeng County of Henan in the south. This region demonstrated the most concentrated ESVs in the Yellow River Basin. The ESVs of 31 research units in the basin were greater than 10.00×10^8 CNY/a. The total ESV in Linqi County was 49.03×10^8 CNY/a, which was the highest among all research units in the Yellow River Basin, followed by Liquan County and Hancheng City in Shaanxi, with the ESVs of 43.63×10^8 and 38.62×10^8 CNY/a, respectively. The third region (III) was the Weihe River Basin, extending from the west of Li County in Gansu to the middle of Shaanxi. There were three research units in this region, with the ESVs of higher than 10.00×10^8 CNY/a. The fourth region (IV) was upstream in the Qinghai-Gansu-Ningxia-Mongolia zone along the Yellow River, extending from Xinghai County of Qinghai in the west to Urad Front Banner of Inner Mongolia in the northeast. This region was located in arid and semi-arid areas, where only one research unit had an ESV exceeding 10.00×10^8 CNY/a.

To avoid confounding effects due to variations in the total area of research units, we calculated the ESVs of gardens per unit area for each research unit. Figure 4 displays the ESVs of gardens per unit area in the research units in the Yellow River Basin. The result shows that the spatial distribution of the ESVs of gardens per unit area was much more concentrated. Among them, the highest ESV of gardens per unit area was found in Liquan County, at 4.22×10^4 CNY/(hm$^2\cdot$a), followed by Linqi City and Hancheng City, at 3.61×10^4 and 2.45×10^4 CNY/(hm$^2\cdot$a), respectively.
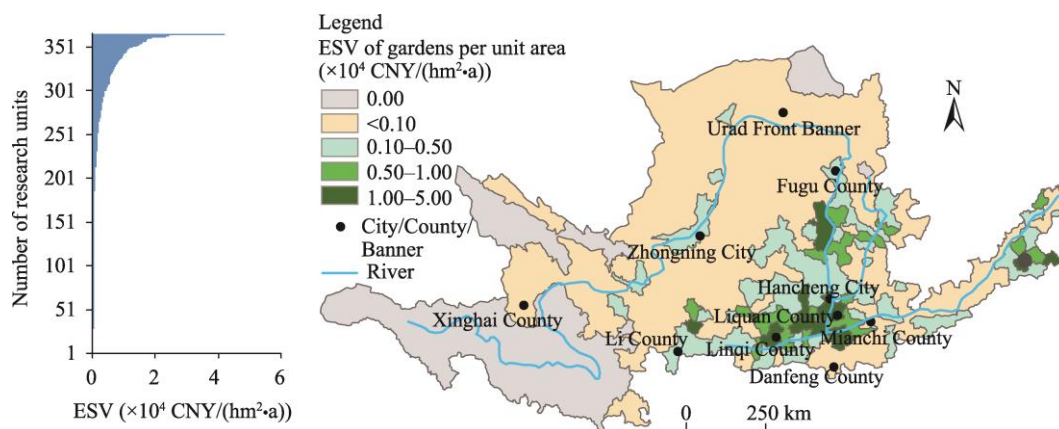
The spatial distribution of the ESVs of gardens was affected by topography, climate, and water resources. The ESVs of gardens were significantly higher in the first and second ladders than in the third ladder and were more extensive in humid and semi-humid areas than in semi-arid and arid areas. Further, the ESVs of gardens were relatively concentrated along the Yellow River and its tributaries.

**Fig. 2** Frequency histogram of the ecosystem service values (ESVs) of gardens in the Yellow River Basin
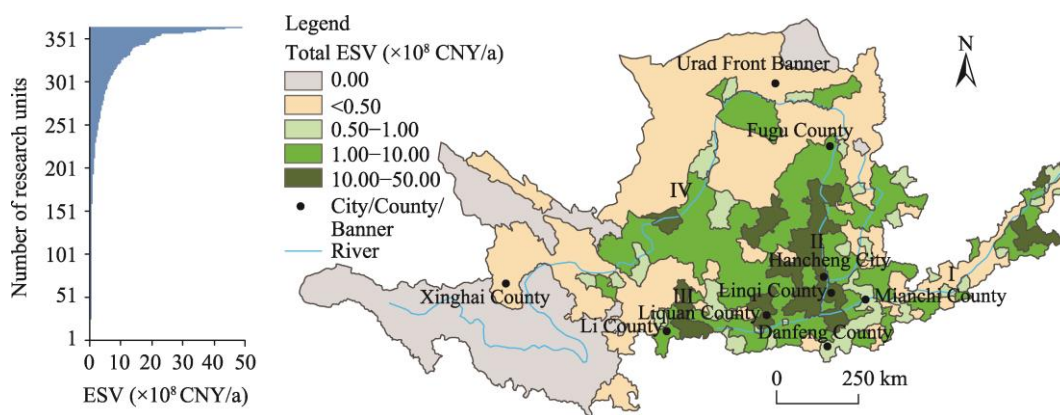
Fig. 3 Histogram (a) and spatial distribution (b) of the ESVs of gardens in the Yellow River Basin. I, II, III, and IV represent four regions in terms of the ESVs in the Yellow River Basin.


Fig. 4 Histogram (a) and spatial distribution (b) of the ESVs of gardens per unit area in the Yellow River Basin

3.2.3 Spatial autocorrelation characteristics

Spatial autocorrelation analysis was used to analyze the distribution characteristics of the ESVs of gardens in the basin. Figure 5 shows that the spatial correlation of the ESVs of gardens in the basin was significant (Moran's I: 0.464), as calculated by Equation 4, and high values adjacent to high values were apparent in the spatial distribution. In the upper reaches of the Yellow River and in the northern part of the Yellow River Basin, low ESVs were adjacent to low values, and the high ESVs were concentrated in the middle and lower reaches of the river (Fig. 6).
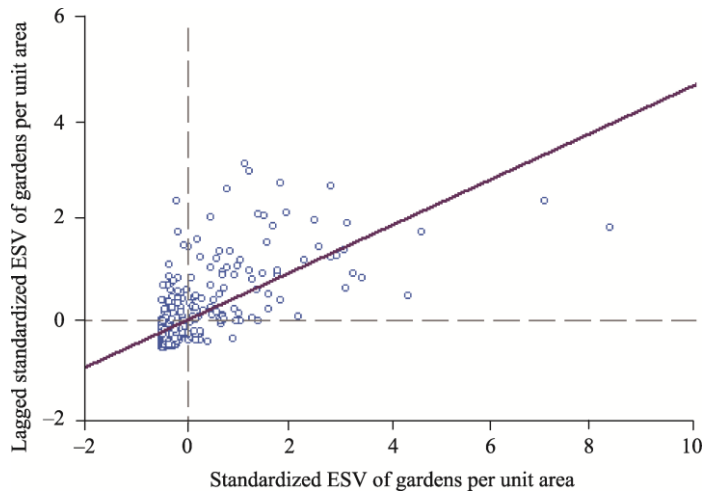
Fig. 5   Spatial autocorrelation of the ESVs of gardens in the Yellow River Basin
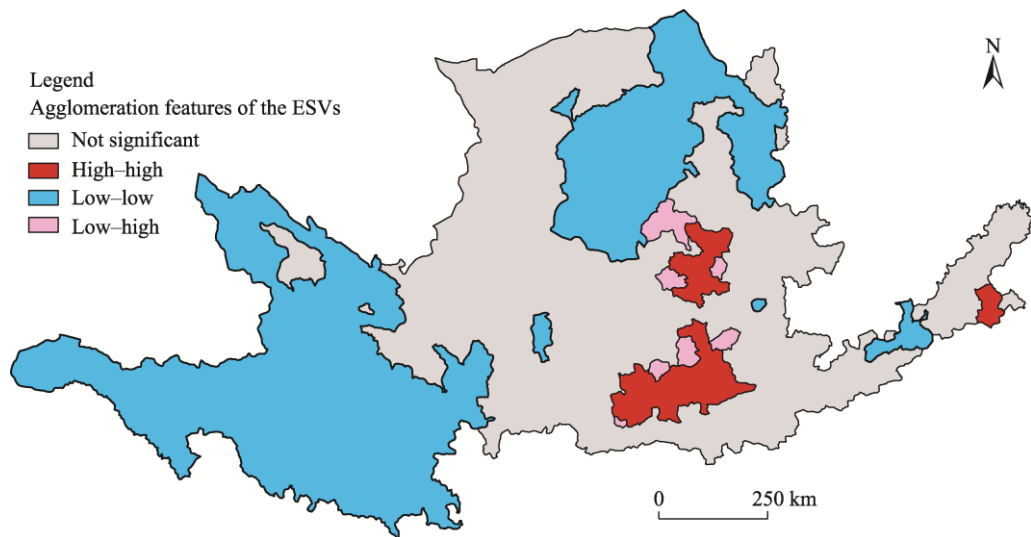
Fig. 6   Agglomeration features of the ESVs of gardens in the Yellow River Basin

4   Discussion

Gardens are usually classified into forests in the evaluation of ecosystem services (Li et al., 2016b; Song and Deng, 2017), and few studies have been done on the ESVs of gardens. As the result of ecosystem service classification system (Constanza et al., 1997; Millennium Ecosystem Assessment, 2005; Kumar, 2010; European Environment Agency, 2022), along with differences in methods adopted by researchers, time of the evaluation, and subjective cognition of evaluators (Xue et al., 2018), assessment results for the ESVs of garden ecosystem and forest ecosystem may vary greatly among different studies (Table 3). This paper objectively reflects the essential characteristics of the ESVs of gardens, and the evaluation results are also within a reasonable range. Therefore, the findings of this paper would be a useful supplement to previous studies of the ESVs of garden ecosystem.

Compared with the total ESV of gardens, the ESVs of gardens per unit area could more accurately describe the spatial distribution of the ESVs of gardens in the Yellow River Basin. The ESVs of gardens were more concentrated in humid and semi-humid areas with abundant precipitation and less distributed in semi-arid and arid areas with scarce precipitation, while there

was an aggregation of the ESVs along the rivers where water resources were abundant. These results are consistent with previous studies of Li et al. (2016a) and Liu et al. (2021) on the ecosystem services in the Yellow River Basin at the county level. In addition, economic and social development also had a certain impact on the distribution of the ESVs of gardens, and the contribution of the ESVs of gardens to the economy and society varied from region to region. The ESVs of gardens were found to be more important for areas with fragile ecological environment and relatively undeveloped economy.

Table 3   Evaluation results for the ESVs of garden ecosystem and forest ecosystem in sample projects

Reference	Year	Study area	Ecosystem	ESV ($\times10^4$ CNY/(hm^2·a))
Costanza et al. (1997)[*]	1997	Global region	Forest	1.02
Costanza et al. (2014)[*]	2010	Global region	Forest	2.89
de Groot et al. (2012)[*]	2012	Global region	Tropical forest	3.33
			Temperate forest	1.91
			Woodland	1.01
Xie et al. (2003)	2002	Tibetan Plateau, China	Forest	1.93
Xie et al. (2015)	2010	China	Coniferous forest	5.97
			Coniferous broad-leaved mixed forest	7.87
			Broad-leaved forest	7.82
Ojea et al. (2016)[*]	2014	Global region	Forest in REDD countries	11.52
			Forest in non-REDD countries	2.65
Cao et al. (2018)	2014	China	Artificial forest	4.60
			Natural Forest	4.32
Qian et al. (2020)	2015	The southern slope of Qilian Mountains, China	Forest	1.70
Xue et al. (2018)	2015	China	Forest	8.88
Grammatikopoulou and Vackárová (2021)[*]	2016	Europe	Mediterranean forest	0.23
			Temperate broad-leaved & mixed forest	0.08
			Temperate conifer forest	0.84
Hu et al. (2021)	2018	Xishuangbanna, China	Tea garden	1.46
			Forest	2.20
			Orchard	8.58
This study	2019	YRB, China	Tea garden	5.49
			Other garden types	8.68

Note: [*], values were obtained on the basis of the exchange rate in the current year. REDD, Reducing Emissions from Deforestation and Forest Degradation.

To sum up, garden ecosystem generally has high ESVs, and relevant measures should be taken to protect and develop this ecosystem appropriately. In areas with concentrated distributions of the ESVs, gardens should be developed in terms of the current situation of garden planting and local advantages, and excessive felling should be strictly prohibited. In the northwest of the Yellow River Basin where the ESVs of gardens were low, the development of gardens should be moderately encouraged to protect the local fragile ecological environment and contribute to poverty alleviation. Gardens should be included in the new round of territory spatial planning, and the regional objectives of garden protection and rational utilization should be put forward.

The evaluation of the ESVs of gardens in the Yellow River Basin is a meaningful endeavor that is worthy of study from different angles. Future work should adopt more methods and be carried out over longer periods of time. Further research is needed to reveal the trends in the development

of the ESVs of gardens in the Yellow River Basin and provide policy guidance for the protection and utilization of local ecosystems.

5   Conclusions

Based on the high-resolution land survey and statistic data, this paper studied the ESVs of gardens in the Yellow River Basin in 2019. Results show that garden ecosystem had high ESVs, with the total value of 1348.66×10^8 CNY/a. Food production was an important service function of garden ecosystem, with the ESV reaching up to 331.86×10^8 CNY/a. The most concentrated areas with high ESVs were mainly located downstream in the Shandong-Henan zone along the Yellow River, mid-stream in the Shanxi-Shaanxi zone along the Yellow River, upstream of the Qinghai-Gansu-Ningxia-Mongolia zone along the Yellow River, and in the Weihe River Basin. Furthermore, the contribution of the ESVs of gardens to the local environment and social economy was also different from region to region. In conclusion, the findings of this study can contribute to the research of ecosystem service evaluation, and the recommendations we proposed are helpful for policy decisions to promote the construction of ecological civilization in the Yellow River Basin.

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